Structural aspects related to the vacuum vessel of the SHIP Project

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- Structural concept and design
- Prototypes proposal for design validation
  - Tests on prototypes

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- Constructive method
  - Execution
  - Transportation
  - Quality control
Reference standards for structural design and checks

- Eurocode 3: Design of steel structures - Part 1-5: Plated structural elements;
- NTC 2008: Italian code.
Relevant structural verification

- **Serviceability limit states:**
  - Vertical and horizontal deflection $\rightarrow$ EC3 1-1 point 7 – Has been limited the deflection in $h_{\text{ave}}/500$. Codes typically indicate $h_{\text{max}}/L=1/200 \div 1/500$. Considering the relevance of the vacuum vessel structure, a deflection limit of $1/500$ has been selected to be on the safe side.

- **Ultimate limit states:**
  - Resistance of cross-sections $\rightarrow$ EC3 1-1 point 6.2;
  - Buckling resistance of members $\rightarrow$ EC3 1-1 point 6.3;
  - Reduced stress method $\rightarrow$ EC3 1-5 point 10 – Effect of shear lag and of plate buckling;
Construction phase – tridimensional final model
Construction phase – tridimensional final model
Construction phase – Basic parts

Depth of each module 2,4 m (dimension governed by transportation constraints)
To reduce corner effects, it is proposed to round them.
Construction phase – Assembling parts
Construction phase – Assembling parts
Construction phase – Assembling parts
Construction phase – Assembling parts

1. Bottom closure element
2. Lateral closure element
3. Top closure element
Construction phase – Assembling parts

Detail of the lifting hook
Construction phase – Assembling parts

SECTION ON A FRAME

INTERMEDIATE SECTION
Construction phase – Welded joints

Det. 1

Det. 2

Det. 3

$\frac{1}{4}$ of pipe Ø 355.6 th. 30 mm
Construction phase – Welded joints

Det. 1
Welding in workshop
WPAR support GB0030 / 04

Det. 2
Welding in workshop
WPAR support GB0030 / 04

Section "A"
Construction phase – Welded joints

Welding carried out on site
WPAR support GB0067 / 07

Section "B"

Welding carried out on site
WPAR support GB0067 / 07
Construction phase – Welded joints

Section "C"

Welding in workshop
WPAR support GB0026 / 04

t1 > t2 ≥ 5 mm
Construction phase – Welded joints

$\frac{1}{4}$ of pipe $\varnothing$ 355.6 th. 30 mm
Construction phase – Bolted joints

- n° 8 M20x75 cl. 10.9 – UNI EN14399 HV
- n° 4 M20x70 cl. 10.9 – UNI EN14399 HV

Shear Heel full round ø 50 mm

Anchoring bolts M30 cl. 8.8

Var. 407 - 2,794 mm
Prototype proposal

• Static test (reduced scale or in real scale):
  o Bending moment test and tensile strength test on portion assembled in workshop and in situ;
  o Test on cross-section of vessel under Serviceability condition for a long time.

• Dynamic tests:
  o Shaking table test on a reduced scale prototype (max dimensions: length=3.0 m; Width=2.4 m; Height=4.0 m).
Main Laboratory Equipment – Static test

Universal machine, height between 0,4 m and e 4,2 m. Actuator in displacement (max displacement +/- 75 mm) or load control (max load in compression 3000 kN, in tension 2400 kN).

Tipi di test:
• Compressione;
• Trazione;
• Flessione.
Main Laboratory Equipment – Static test

Universal MTS810 for tension, compression, cyclic and fatigue tests on samples with maximum height of 1.4 m, in load control (max load +/- 500 kN) or displacement control (max displacement +/- 75 mm).

Tipi di test:
• Compressione;
• Trazione.
Main Laboratory Equipment – Static test

Universal machine, height from 1.5 up to 4.8 m. Actuator in displacement (max displacement +/- 125 mm) or load control (max load in compression 30,000 kN, in tension 20,000 kN).

Tipi di test:
• Compressione;
• Trazione;
• Flessione.
Main Laboratory Equipment

Shaking tables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOF</td>
<td>2 each table</td>
</tr>
<tr>
<td>Dimension</td>
<td>3,0 m x 3,0 m</td>
</tr>
<tr>
<td>Max payload</td>
<td>20 t</td>
</tr>
<tr>
<td>Acceleration peak</td>
<td>1,0 g</td>
</tr>
<tr>
<td>Weight for one table</td>
<td>63 t</td>
</tr>
<tr>
<td>Displacement peak</td>
<td>± 250 mm each axis</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0÷50 Hz</td>
</tr>
</tbody>
</table>

The tables system can work in an independent way or can be combined to form one big table (3 m x 7 m).

Prototype of bridge piers across a fault

Closed system = actuators and servovalves inside

Possibility of motion